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[Farhan Azam](#) *

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Article

Removal of Lead (Pb(II)) from Water by Adsorption Using Nagar Parker Kaolin Clay

Farhan Azam

University of the Punjab; farhan.azam5656@gmail.com

Abstract: Clean water is now very rare due to the increased water pollution causing many diseases. Heavy metals mainly lead from industrial waste i.e. batteries, cable sheaths, machinery manufacturing, shipbuilding, lead oxide and radiation protection is accountable & largely contributed lead in river and canal waters. Presence of lead in water is hazardous to life due to many reasons. It can cause cancer, weakness, anemia, kidneys, high blood pressure and nerve diseases. Inorganic lead is reported to be more dangerous than organic one. Industries including batteries, cable sheaths, machinery manufacturing etc. drains water that has soluble lead ranging from 200 – 500 mg/L. The safe limit of lead in water is about 0.015 mg/L. Pakistan is a country rich in minerals. It has about 3.5 MT of Kaolin (Clay) deposits situated at Nagar Parker region of Sindh, Pakistan. This indigenous material is being used to produce ceramic products and in paper making. Now we use this mineral source to remove lead from water by adsorption. Kaolin clay can be used as an adsorbent due to its unique structure. XRF technique is employed for clay characterization. Resultants will be analyzed by UV – Vis Spectrophotometry.

Keywords: lead removal; adsorption; isotherms; nagar parker clay; adsorption kinetics

1. Introduction

Water and environmental pollution are producing by human activities. Nowadays water is a global problem. Contamination of harmful heavy metals, organic and inorganic pollutants effect the ecosystem. Fresh and clean water is the basic need of all living things wather it is use for drinking purposes or commercial use. Contaminated and poor cleanliness of water are the major source different of diseases like cholera, typhoid, diarrhea, and hepatitis. It has reported that about 6 million children die daily due to waterborne disease and most of the population of Asia and Africa doesn't have clean water for drinking [1,2].

Currently this wastewater mixed with ground water and polluted it. The discharge of lead wastewater in rivers, canals effect our food things. The presence of small amount of lead in water produce skin, hearth, and kidney etc. According to world health organization the amount of lead is 0.1 mg/l [3].

Many technologies are being used for water treatment like adsorption, photo-catalysis, filtration and ion exchange process, electro-dialysis, chemical precipitation. Each of these technologies have its own advantages and disadvantages [4,5].

Recent studies show that the adsorption is one of the best and well-known equilibrium separation process for water treatment. Adsorption has also been found preferable to other methods because it's easy and simple operation, low cost, flexible and simplicity in design and insensitivity to noxious pollutants [6]. Adsorption not only eliminate but it can also recover and recycle them to the industrial processes [7,8].

2. Material and Method

2.1. Materials

Large pieces of kaolin clay obtained from Nagar parker region of Thar parker district of Sindh province in Pakistan. These pieces are sent to crusher and converted into powder form. Take 50gm

clay powder and mixed in 500 ml deionized water. The mixture is stirred for 2 hr at 25 °C. Obtained mixture product is placed for sedimentation for 2 hr and then filter the product. The obtained kaolin gel like material is dried at 100 °C for 2 hr in drying oven. The obtained material is finally grinded and passed through 200 mesh size screens to obtained fine powder. This clay powder is stored in airtight bags to use further [9].

The elemental properties of kaolin are tested before and After washing kaolin. PW 2400 x-ray spectrophotometer is used to analyze the samples.

Table 4. composition of kaolin clay.

Oxides	Raw Kaolin (wt%)	Washed Kaolin (wt%)
SiO ₂	47.691	44.958
Al ₂ O ₃	26.529	34.559
Na ₂ O	1.302	1.241
TiO ₂	0.502	0.610
Fe ₂ O ₃	1.052	1.057
MgO	0.596	0.573
CaO	5.833	2.356
K ₂ O	0.591	0.590
Cl ₂	0.752	0
LOI	15.152	14.056

LOI (Loss on ignition) at 1000 °C.

Sigma Aldrich laboratory grade lead Nitrate (99%) is used. Take 1.6gm lead nitrate salt and mixed in deionized water to prepared stock solution. In the whole process deionized water is used because tap or other source of water contain other metal ions in it and compete with lead in adsorption process so the correct percentage of lead removal would not be determined [10].

2.2. Method

Kaolin is added in the solution about 1g per 250ml of solution which is than stirred for 3hr using magnetic stirrer after stirring the slurry is equilibrated for 24 hrs. It will be than filtered and water sample will be tested for lead removal by Parkin Almer UV-spectrophotometer. Different concentrations and adsorbent dosage are changed and repeat same procedure to study the effect.

Results and Discussions

4.2.1. Effect of Concentration

Concentration effect is checked by preparing different concentration solutions. Adding 1g kaolin in 250 ml of different concentration solution of lead nitrate. The prepared samples are mixed using magnetic stirrer for 2 hr at 5.5 pH of solution and room temperature to obtained equilibrium in solution.

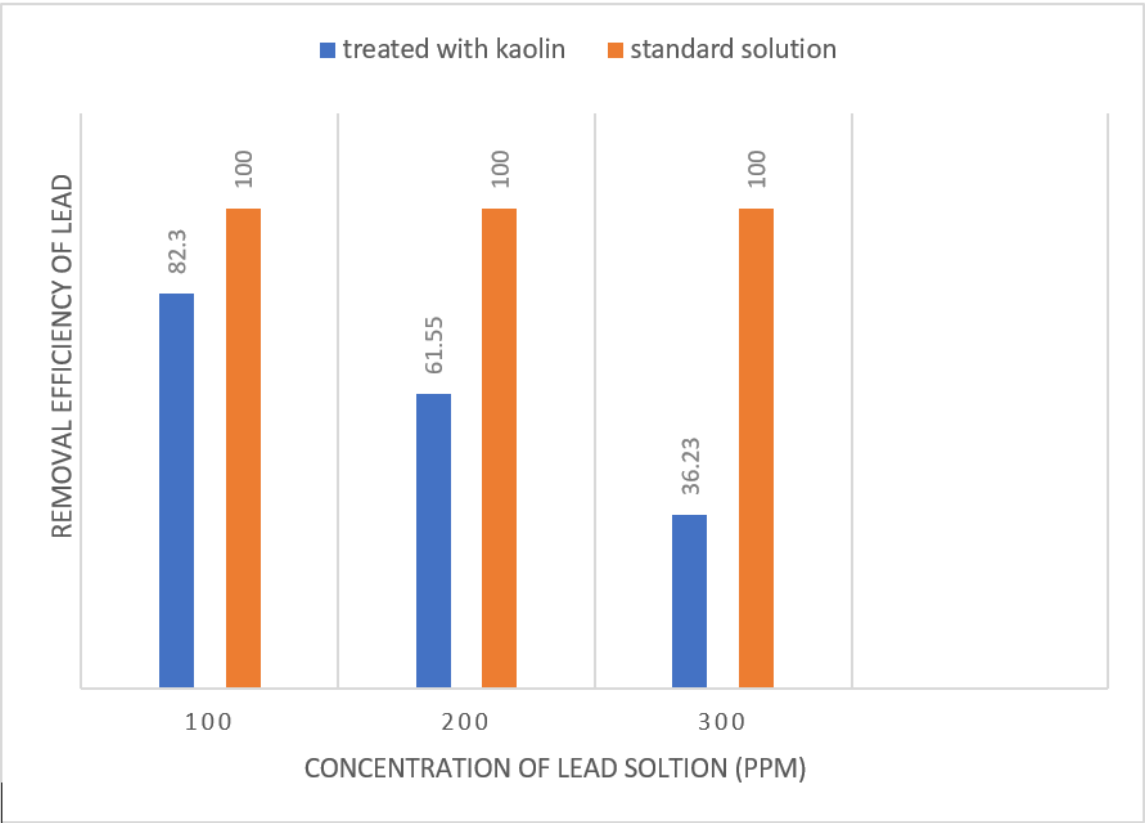


Figure 14. Effect of kaolin on different concentration of Lead solution.

The equilibrium time reported in the literature for the adsorption of kaolin is 60 min. There is only 10% increase in lead removal by varying the time from 40min to 160 min [45].

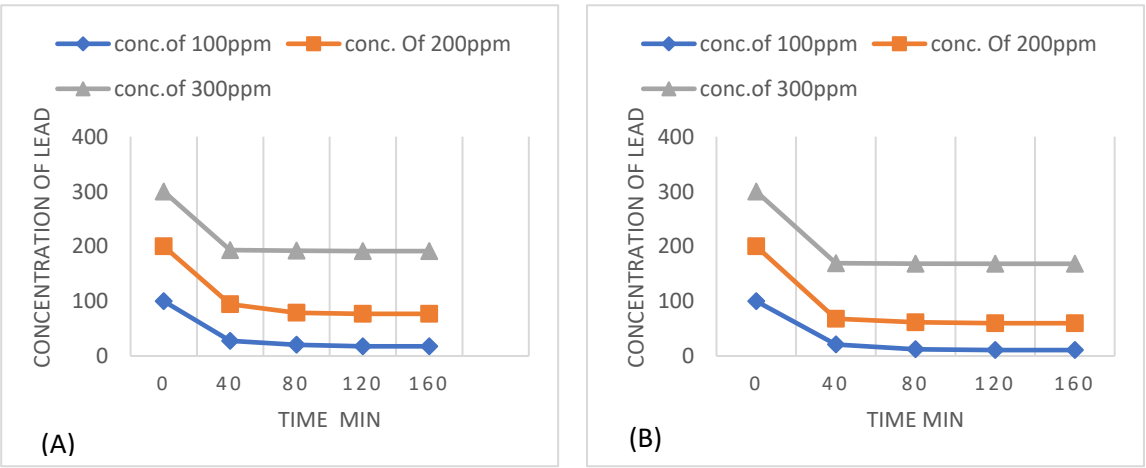


Figure 15. Effect of concentration of lead with respect to time with (A) 1g kaolin (B) 2g kaolin.

Formula:

$$\% \text{ of lead adsorbed} = \frac{\text{initial cocentration} - \text{final concentartion}}{\text{initial concentration}} * 100 \tag{2}$$

Using the above formula calculate the efficiency of different solutions and draw graph and maximum lead is removed from solution using kaolin adsorbent.

It is observed from the chart that by decreasing concentration from 300ppm to 100ppm lead removal is increased from 36% to 82%. Different adsorbents are used to remove lead from water.

Researches that used bone powder, active carbon, plant powder and commercial carbon. Bone powder has removed lead capacity of 100%, active carbon has 90%, plant powder has 80% and commercial carbon has 50%.

4.2.2. Effect of Dosage

Effect of 1g of kaolin clay is calculated. Now to study the effect of dosage the quantity of kaolin is increased. Take 250 ml solutions of lead with different concentration and add 2g kaolin in it. Same conditions are applied like 1g kaolin dosage experiment and results are calculated.

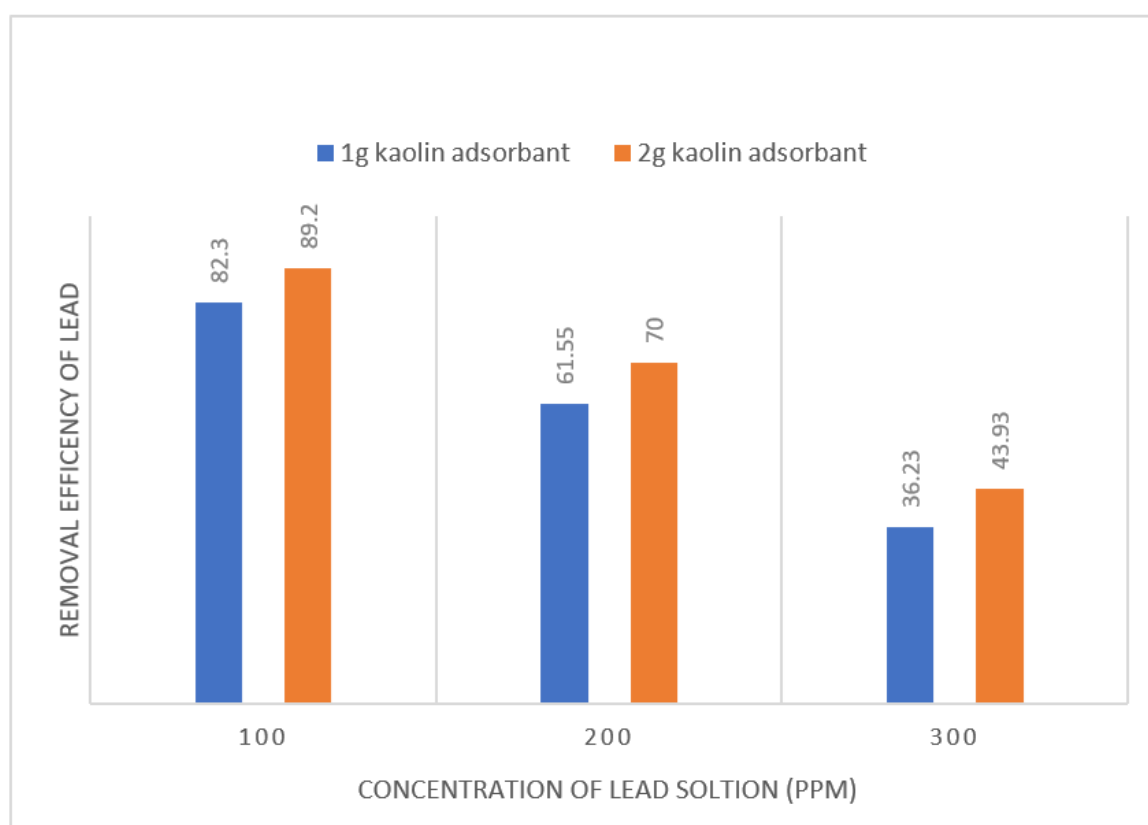


Figure 16. Effect of kaolin dosage on removal of lead at same concentration.

The removal efficiency of kaolin is improved by increasing dosage of kaolin. The removal efficiency of 100, 200 and 300 ppm solutions for 1g and 2g kaolin dosage are 82 to 89%, 62 to 70% and 36 to 43% respectively.

The purpose of varying the quantity of adsorbent is to be checked how much increase in lead removal from water that is 7%, 8% and 7% for 100, 200 and 300ppm solution.

4.2.3. Effect of pH

Prepare solutions to check pH effect of solution on adsorption was determined by taking 250 ml lead solution add 1g kaolin in solution containing lead concentration of 100 ppm and adjust pH values ranging from 3.0 to 9 using 0.1M HCl and NaOH solutions. The mixture was shaken for 60 minutes at normal room temperature and then the filtered and examined the solution. The pH is an important controlling parameter in the adsorption process.

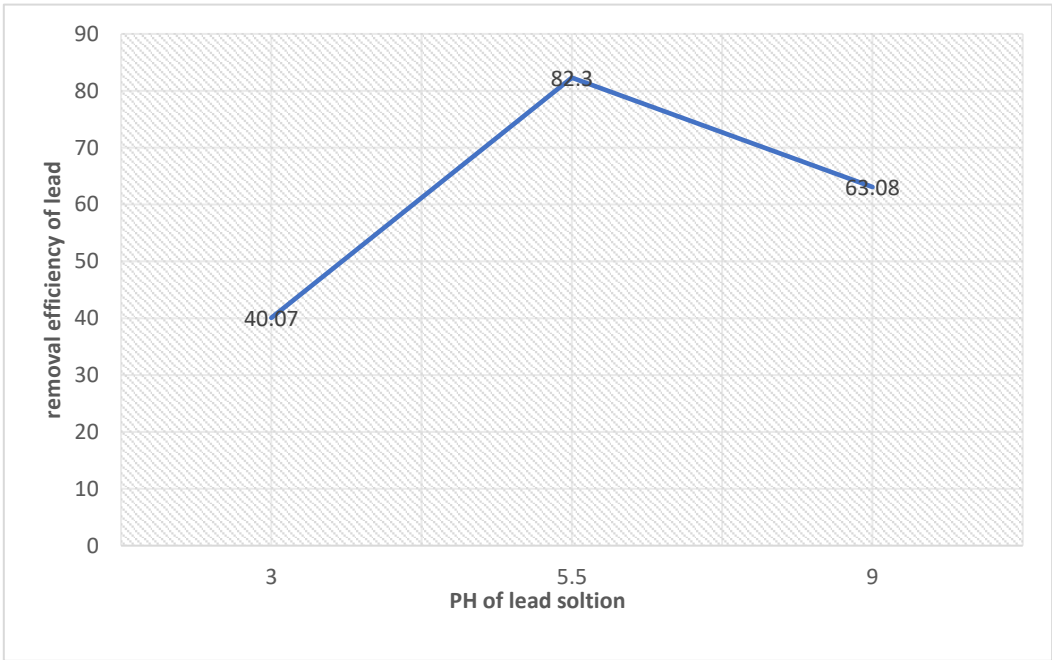


Figure 17. Effect of pH with respect to removal efficiency of lead.

Figure shows the effect of pH on amount of metal ion adsorbed; removal efficiency is calculated using formula. Figure also shows that Pb+2 adsorption shows the maximum efficiency at pH of 5.5. It means that the removal of lead ions increases when the solution pH increased from 3.0 to 6.0. The pH range was chosen as 3 to 6 in order to avoid metal hydroxides, which has been estimated to occur at pH> 6.5 [30]. when pH increases, there is a decrease in positive surface charge.

4.2.4. Effect of time

The effect of time of Pb(II) ions onto kaolin clay was done by using 100, 200,300ppm concentration of Pb(II) at initial pH 5.5 onto(1.0 and 2.0 g/250 mL) of adsorbent dose.

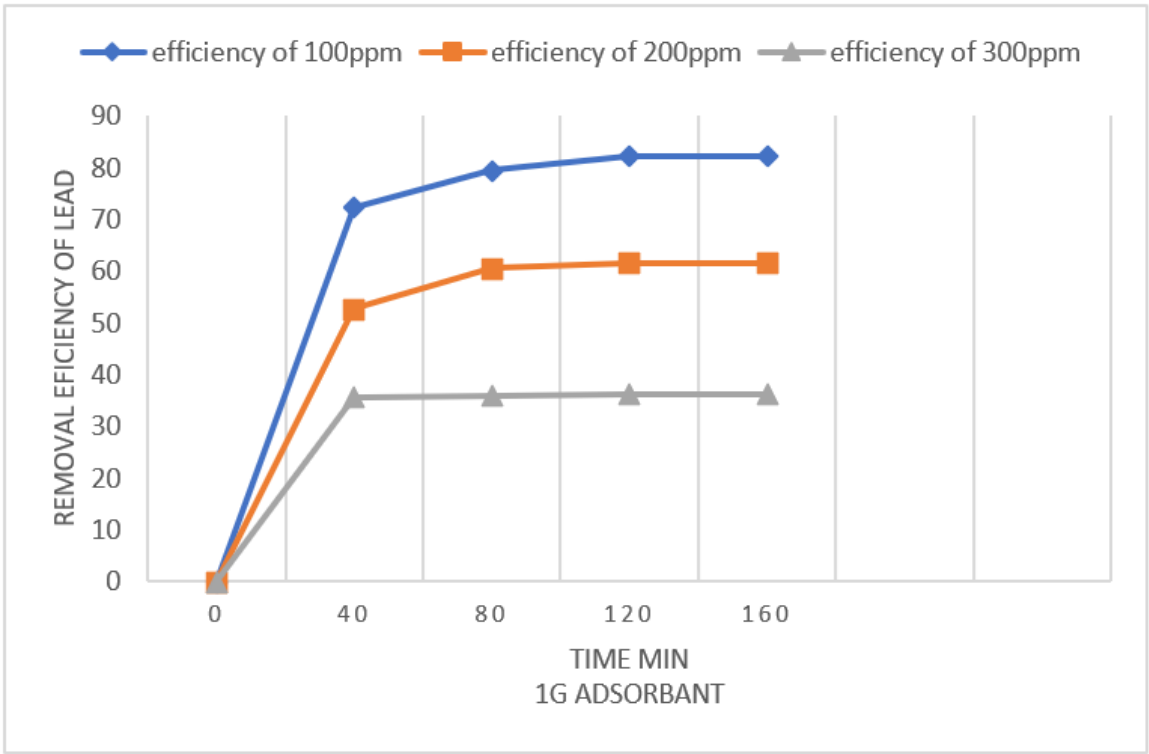
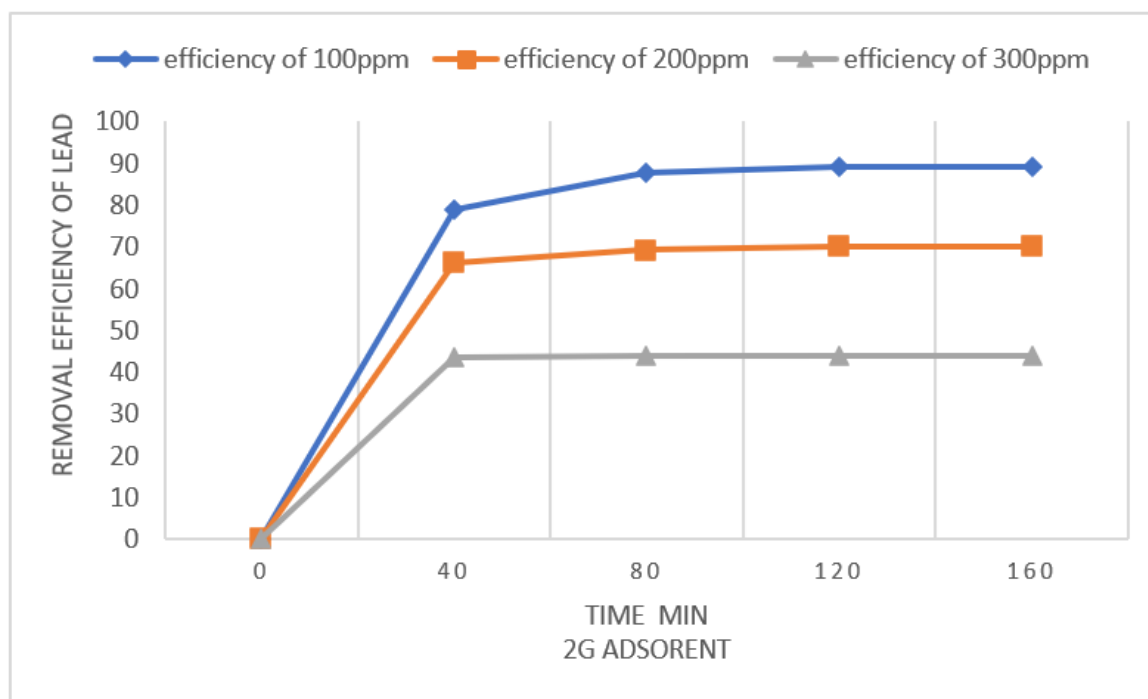


Figure 18. Effect of time on removal efficiency of lead with 1g adsorbent dosage.**Figure 19.** Effect of time on removal efficiency of lead with 2g adsorbent dosage.

The lead adsorption is maximum at the start because adsorbent places are free and lead ions easily attached with these places. A larger amount of Pb(II) was removed in first 60 mins of time content, and after that Pb(II) remove slowly till equilibrium time (2 h).

4.5. Adsorption Isotherms

The adsorption isotherms are important to study mechanism of the adsorption. Adsorption isotherm have different equations and two isotherms are selected to study, which are Langmuir and Freundlich isotherms.

4.5.1. Langmuir Isotherm

In Langmuir adsorption isotherm adsorption takes place at specific homogeneous sites within the adsorbent and has found successful applications in many adsorption processes of monolayer adsorption. The Langmuir isotherm equation is represented by the following:

$$C_e/q_e = 1/(b \cdot q_{\max}) + (1/q_{\max}) C_e$$

Where

$q_{\max}$ = Maximum adsorption capacity (mg/g)

b = Langmuir constant (L/mg)

Plot a graph between C_e/q_e and C_e for the adsorption of lead(II) ions onto kaolin clay.

$1/q_{\max}$ = slop of the straight line and

$1/(q_{\max} b)$ = intercept of line.

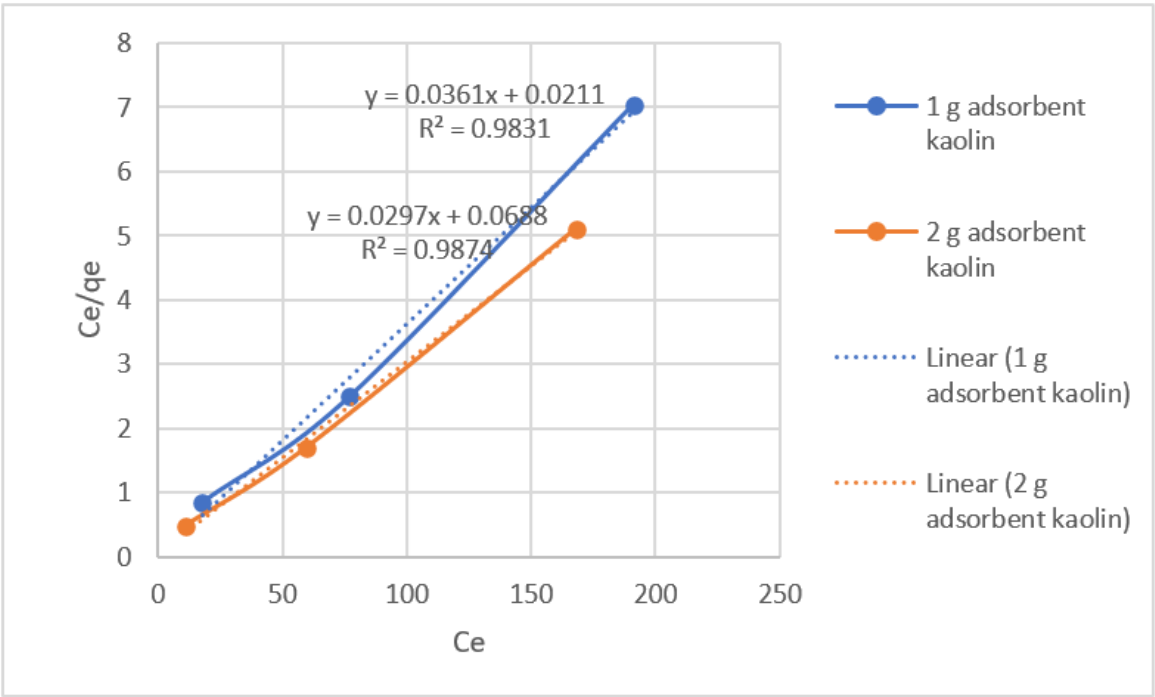


Figure 20. Langmuir adsorption of lead ions onto different adsorbent amount at room temperature.

Adsorbent Amount		Langmuir Isotherm Constants		
Adsorbent /250ml	qmax (mg/g)	b (L/mg)	R ²	
1-gram adsorbent	27.70	1.71	0.9831	
2-gram adsorbent	33.67	0.432	0.9874	

4.5.2. Freundlich Isotherm:

The Freundlich isotherm is an empirical equation used to explain heterogeneous systems. The Freundlich isotherm equation is:
 $\ln q_e = \ln K_F + 1/n \ln C_e$
where
KF and n = Freundlich constants
KF and n respectively indicating the adsorption capacity and the adsorption intensity. They were calculated from the intercept and slope of the plot between $\ln q_e$ and $\ln C_e$ for the adsorption of lead(II) ions onto kaolin.

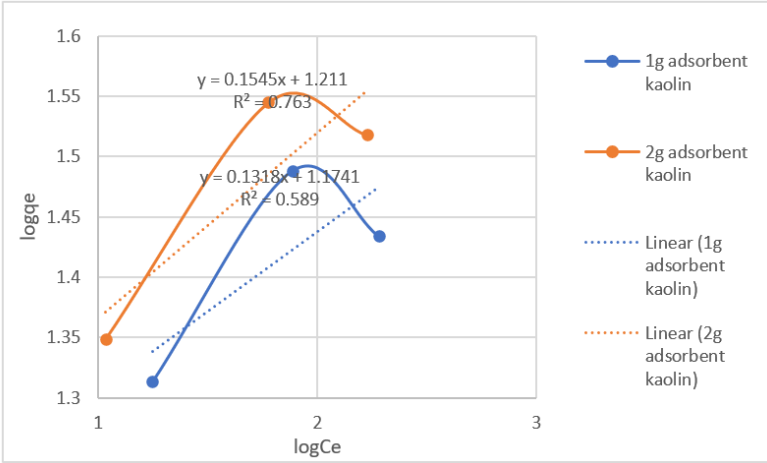


Figure 21. Freundlich adsorption onto different amount of adsorbent at room temperature.

Adsorbent Amount		Freundlich Isotherm Constants	
Adsorbent/250mL	KF (L/mg)	n	R ²
1-gram adsorbent	14.93	7.587	0.589
2-gram adsorbent	16.25	6.472	0.763

Results shows that the value of R² is equals to 1 in Langmuir adsorption which means the process lies in Langmuir isotherm and show physical adsorption and process is mono-layer.

4.6. Adsorption Kinetics

$$\ln(q_e - q_t) = \ln q_e - K_1 t \quad (3)$$

$$\frac{t}{q_t} = \left(\frac{1}{K_2}\right)\left(\frac{1}{q_e^2}\right) + \frac{t}{q_e} \quad (4)$$

Using these equations calculate the values of K₁ and K₂

Pseudo First Order Constants			
Metal Ion	q _e (mg/g)	K ₁	R ²
Pb ²⁺	20.575	0.0527	0.979
Pseudo second order constants			
Metal ion	q _e (mg/g)	K ₂	R ²
Pb ²⁺	20.575	0.0088	0.998

The pseudo first and second order values shows that the system lies in pseudo second order and showing higher adherence rate then pseudo first order.

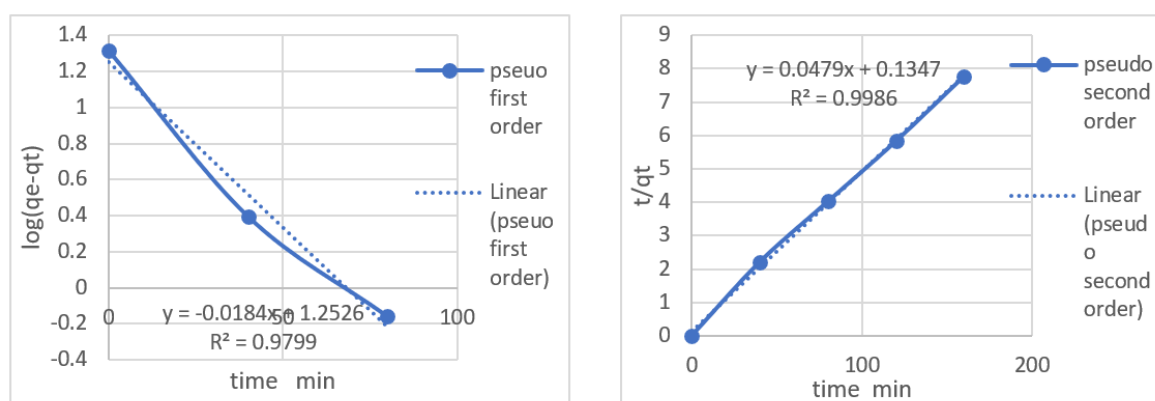


Figure 22. Adsorption kinetics models of lead.

Conclusions

Kaolin composition obtained from Nagar Parker has same to ideal kaolin. The clay has strong potential to remove lead ions from aqueous solutions. The results show that Nagar parker kaolin is a good low-cost adsorbent. The adsorption studies show that metal ion concentration, contact time, PH and adsorbent dosage intensely affected the lead ion adsorption. PH is one of the parameters that strongly effect the metal ion removal.

Kaolin can be regenerated by reacting with NaNO₃ and again it can be used for the remove lead from water. Furthermore, lead removal capacity of kaolin can be enhanced by activation of cation. Cation can be activated through thermal treatment and by reacting with Na, K and calcium chlorides.

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